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Setting-up a billboard of marine invasive species in the ESENIAS area: current situation and future expectancies

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In this study we present a list of invasive/potential invasive alien species in the East and South European Network for Invasive Alien Species (ESENIAS) countries with marine borders. The species were classified according to the existing literature and experts' judgment, as established, casual, invasive and expected. Finally, factsheets were compiled for ten species of high importance based on their expanding/invading character.

Of the 160 species comprising the list, 149 were already present in the ESENIAS countries, while eleven were invasive species either present in the Mediterranean or in other European Seas, likely to be recorded in the ESENIAS countries. The majority of the species were of Red Sea/Indo-Pacific origin (97 species; 60.6%). Italy, Turkey and Greece were the countries with the highest representation of species (159, 152 and 139 species respectively), due to their extended coastline and the number of scholars working on marine invasive species. The highest number of established species was recorded in Turkey (116 species), whereas in Italy and Greece the most numerous species were the "expected" ones (85 and 48 species, respectively). The eastern Adriatic Sea countries (i.e. Albania, Croatia, Montenegro and Slovenia) had generally low numbers of species in this list, many of which are still "expected" to arrive from the neighbouring countries of Greece and Italy. Finally, the most frequently potential pathway was transfer stowaways (ship ballast water: 41 cases; ship hull fouling: 55), whereas unaided spread of Lessepsian immigrants followed (95 cases).

This list is intended to serve as an early warning system that through horizon scanning process would assist ESENIAS countries to prioritise invasive alien species, their pathways and the areas of higher likelihood to appear, in order to take management measures.

Key words: invasive species, ESENIAS, Mediterranean Sea, Black Sea

INTRODUCTION

Biological invasions, both in land and sea, have been worldwide acknowledged as a man-induced ecosystem pressure that should be monitored and managed (ROY *et al*., 2015, 2017). The Mediterranean, has been characterized as a "sea under siege" (GALIL, 2000), due to the large number of marine alien species recorded, which are introduced by a variety of pathways/vectors (ZENETOS *et al.,* 2010, 2012). In particular, the Eastern Mediterranean, due to its proximity to the Suez Canal, has been susceptible to biological invasions and hosts more than 775 alien and cryptogenic species (ZENETOS *et al.,* 2012). Similarly, the Black Sea, an enclosed marine system of particular physicochemical characteristics, low diversity and high marine traffic, is vulnerable to marine invasions (LEPPÄKOSKI & MIHNEA, 1996). Of particular importance among aliens are the invasive alien species (IAS), which are considered one of the greatest threats to biodiversity and on ecosystem services (KATSANEVAKIS *et al.,* 2014).

Several international agreements such as the Convention on Biological Diversity (CBD), the EU Biodiversity Strategy (EU, 2011), and the European Marine Strategy Framework Directive (EU, 2008), recognise the negative impacts of IAS and highlight the growing concerns of policy-makers, scientists, stakeholders and society.

It is widely acknowledged among scientists that an early warning system should be elaborated, and one of the best ways is through horizon scanning (ESSL *et al.,* 2015; ROY *et al.,* 2015, 2017; and references therein). Horizon scanning is the process of gathering, analysing and disseminating added-value information to support decision-making (ROY *et al.,* 2014). However, for most regional seas, lists of current or future biological invasions are not available to date. This is also the case for many countries in the Mediterranean region regarding invasive species in the marine environment. Moreover, it is essential to prioritise IAS, their pathways and the areas of higher likelihood to appear, in order to manage and successfully encounter IAS issues (MCGEOCH *et al.,* 2016).

In the present study, effort has been made to compile a list of marine IAS in the network of the ESENIAS (East and South European Network for Invasive Alien Species) countries, including those species already present in this area and those with a high likelihood of appearance. The aim of this work was to create a catalogue (list of invasive / potential invasive species of ESENIAS concern) to serve as a basis for an early warning system, through a horizon scanning process (ROY *et al.,* 2015). This would allow ESENIAS countries to a) identify the most harmful species within the ESENIAS area; b) support the establishment of an effective early warning and rapid response mechanisms; c) support any eradication attempts of prioritised species at an early stage of invasion, and d) take management measures for IAS that are already widely spread, as requested by the EU Regulation No 1143/2014 (EU, 2014). Detailed fact sheets of the ten most important species, based on their invasive potential, were also assembled.

MATERIAL AND METHODS

In the framework of ESENIAS-Tools project, a list of invasive/potential invasive species in the ESENIAS countries with marine borders (Albania, Bulgaria, Croatia, Greece, Italy, Montenegro, Romania, Slovenia, and Turkey) was built up. The criteria used for this compilation were the following: a) invasive species already present in the area as reported in the national lists or other literature; b) invasive species in the Mediterranean/Black Sea that have not yet exhibited invasive behaviour in ESENIAS countries and c) invasive species in European Seas, which are likely to invade ESENIAS countries. Cryptogenic species were not considered.

Consequently, based on the existing literature, as well as on expert judgment, the species were classified for the ESENIAS area in the countries as established (species with an already established population in the area), casual (species with just one or few records in the country), invasive (species that are established/invading, with effects – positive and/or negative – on the ecosystem and its services), unknown (species whose presence/status in a country is not yet clarified), and expected (species likely to appear in a country, based on expert judgment and their presence in adjacent areas, and their ecological/environmental requirements). This latter category was further expanded for Croatia and Italy, as expected in the southern and northern parts of the country. The list also includes the species' origin and potential pathway/vector of introduction (CBD, 2014).

Finally, fact sheets were compiled for ten species that were commonly agreed, among experts, as of high importance. The decision was based on their expanding/invading character according to biological traits and existing data on their invasion history, combined with the absence of published fact sheets at the time (January 2016), excepting *Mya arenaria* that has recently invaded the Adriatic Sea (CROCETTA & TUROLLA, 2011). Each fact sheet includes the following information: a) description and diagnostic features; b) biology and ecology; c) habitat and distribution (both native and in the ESENIAS area); d) pathway/vector of introduction; e) impacts on biodiversity, ecosystem services and human health; and f) risk assessment and management (when applicable). Maps presented here include information until August 2017. The full fact sheets are published at the ESENIAS Scientific Reports (TRICHKOVA *et al.*, 2017), whereas here only a brief account per species is given.

RESULTS AND DISCUSSION

The list of invasive/potential invasive species

Overall, 160 species are given in the list, 149 of which are already present in the ESENIAS countries and eleven have not yet been recorded in the area. Approximately two thirds of the species (97 species; 60.6%) were of Red Sea/Indo-Pacific origin, followed by those of Pacific origin (28 species; 17.5%) (Table A, on-line supplement). From the species included in this list, the countries with the highest representation were Italy, Turkey and Greece (159, 152 and 139 species respectively; Table 1; Table A, on-line supplement; Fig. 1). A plausible explanation could be the fact that these countries have the longest coastlines among the ESENIAS ones, as well as the highest number of marine experts working on invasive species (KARACHLE *et al.*, 2017). Moreover, a recent work on marinas across the Mediterranean has added considerably to the distribution of many invasive species in Turkey, Greece and Italy (ULMAN *et al.,* 2017)

Turkey was the country with the highest number of established species (116 species), a fact that it can be attributed to its geographic

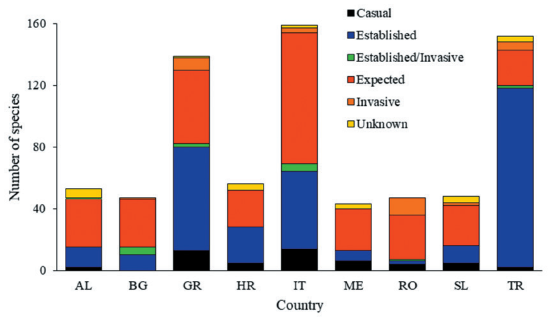

Fig. 1. Number of species per different category in the ESENIAS countries with marine borders (AL=Albania, BG=Bulgaria, GR=Greece, HR=Croatia, IT=Italy, ME=Montenegro, RO=Romania, SL=Slovenia, TR=Turkey)

position and proximity to the Suez canal, and, along with Croatia, had the lowest number of expected ones (23 and 24 species, respectively; Table 1; Table A, on-line supplement; Fig. 1). On the other hand, countries with the most numerous expected species were Italy and Greece (85 and 48 species, respectively) followed by Albania, Bulgaria and Romania (31, 31 and 29 species, respectively). In the case of Italy, the high number could be attributed to three main reasons: a) this country is in the middle of the Mediterranean Sea, and hence has influxes of invasive species from both east (mainly Lessepsian immigrants) and west (Atlantic entries); b) intensive oyster activities, mainly in the northern Adriatic, led to accidental transfer of IAS through mariculture, and is thus vulnerable to similar introductions in the future; and c) the country holds major ports and is susceptible to ship transferred species. The last reason stands also for Bulgaria and Romania in the Black Sea. Concerning Greece, it is strongly affected by the Lessepsian invasion, and, due to the proximity to Turkey that holds a substantial number of established alien species, is likely to receive quite many additional IAS.

Finally, a small number of species represented in the list characterizes the eastern Adriatic Sea countries, i.e. Albania, Croatia, Montenegro and Slovenia, in general. Yet, all the aforementioned counties display a high number of “expected” IAS, compared to their total IAS. This fact could be related to the low number of experts working on alien species in these countries (KARACHLE *et al.*, 2017). In addition, the neighbouring Greece and Italy display high numbers of alien species (e.g. ZENETOS *et al.*, 2015; MARCHINI *et al.*, 2013; ZENETOS & KARACHLE, 2017), many of which have not been reported to date in the East Adriatic countries (KATSANEVAKIS *et al.*, 2011).

The vast majority of the listed species (112 species) had only one potential pathway/vector of introduction, while the remaining ones had either two (42 species) or even three (6 species) pathways/vectors (Table A, on-line supplement). In 94 cases species were transferred as stowaways (ship ballast water: 39 cases; ship hull fouling: 55), whereas in 95 cases species were Lessepsian immigrants.

There were only 15 species transported as contaminants on animals (accidentally with aquaculture) and 10 species by other vectors (aquaria intentional releases, aquaculture escapees) (Table A, on-line supplement). It should be noted that invasive cold water species introduced as contaminants in Northern Europe are likely to be introduced to the Black Sea countries and Northern Adriatic but not to the southern countries. In this context, tropical species that are already invasive in the Levantine are more likely to spread in the southern countries but not in the Black Sea.

Species’ factsheets: a brief account

Ten species were selected, based on their spreading and invasive character, namely *Alexandrium monilatum* (J.F.Howell), *Bonnemaisonia hamifera* Hariot, *Streblospio gynobranchiata* Rice & Levin, 1998, *Cassiopea andromeda* (Forsskål, 1775) upside down jellyfish, *Oithona davisae* Ferrari & Orsi, 1984, *Penaeus aztecus* Ives, 1891 brown shrimp, *Mya arenaria* Linnaeus, 1758 sand gaper, *Diadema setosum* (Leske, 1778) long-spined sea urchin, *Microcosmus exasperatus* Heller, 1878 and *Pterois miles* (Bennett, 1828) Devil firefish/lionfish. The major pathway/vector of introduction for the above mentioned species was transfer stowaways (ship ballast water: 9 cases; ship hull foul-

*Table 1. List of present (absent species are indicated by an asterisk *), and expected invasive species in the ESENIAS countries with marine borders (AL=Albania, BG=Bulgaria, GR=Greece, HR=Croatia, IT=Italy, ME=Montenegro, RO=Romania, SL=Slovenia, TR=Turkey). Est=established, cas=casual, unk=unknown establishment status, inv=invasive, exp=expected (expS=expected south; expN=expected north). Empty cells indicate that the species has not been reported yet or is expected in the country. Species in bold are those with factsheets compiled within the ESENIAS-Tools project*

	Species	AL	BG	GR	HR	IT	ME	RO	SL	TR
	Alexandrium monilatum (J.F.Howell)		est		exp	expN		exp		
	Caulerpa cylindracea Sonder	est		est	est	inv	est		exp	est
	Caulerpa taxifolia (M.Vahl) C.Agardh			exp	est	est			exp	est
	Caulerpa taxifolia var distichophylla (Sonder) Verlaque, Huisman and Procacini			est		est				est
	Codium fragile (Suringar) Hariot	exp	exp	inv	est	est	exp	exp	est	est
	Codium parvulum (Bory de Saint Vincent ex Audouin) P.C.Silva			exp		expS				est
	Acrothamnion preissii (Sonder) E.M.Wollaston		exp		est	est		exp	exp	
	Asparagopsis armata Harvey	exp		est	est	est	unk		est	est
	Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon	est		est	cas	est	est		exp	est
	Bonnemaisonia hamifera Hariot	exp	exp	cas	exp	est	exp	exp	cas	est
*	*Galaxaura rugosa* (J.Ellis & Solander) J.V.Lamouroux			exp		expS				unk
	Gracilaria vermiculophylla (Ohmi) Papenfuss		exp		exp	est		exp	exp	exp
	Lophocladia lallemandii (Montagne) F.Schmitz	est		est	est	est	exp		unk	est
*	*Polyopes lancifolius* (Harvey) Kawaguchi & Wang		exp			expN		exp		
	*Womersleyella setacea (*Hollenberg) R.E.Norris	exp		est	est	est	est		exp	exp
	Sargassum muticum (Yendo) Fensholt		exp			est		exp		
	Stypopodium schimperi (Kützing) M.Verlaque & Boudouresque			est		expS				est
	Undaria pinnatifida (Harvey) Suringar		exp	exp		est		exp		exp
	Halophila stipulacea (Forsskål) Ascherson	est		est		est	exp			est
	Branchiomma bairdi (McIntosh, 1885)			est		est				est
	Branchiomma luctuosum (Grube, 1870)			est		est				est
	Ceratonereis mirabilis Kinberg, 1865			exp		expS				est
	Desdemona ornata Banse, 1957	exp	exp	cas	exp	est	exp	exp	exp	est
	Dipolydora quadrilobata (Jacobi, 1883)		est		exp	expN		inv	exp	
	Dorvillea similis (Crossland, 1924)			cas		expS				est
	Ficopomatus enigmaticus (Fauvel, 1923)	est	est	est	est	inv		est/inv	est	est
	Hydroides operculata (Treadwell, 1929)			exp		expS				est
	Leodice antennata Savigny in Lamarck, 1818			exp		cas				est
	Leonnates indicus Kinberg, 1866			exp		expS				est

Species	AL	BG	GR	HR	IT	ME	RO	SL	TR
Leonnates persicus Wesenberg-Lund, 1949			cas		expS				est
Notomastus mossambicus (Thomassin, 1970)			exp		exp				est
Polydora cornuta Bosc, 1802	exp	est	cas	exp	est	exp	inv	exp	est
Prionospio krusadensis Fauvel, 1929			exp		expS				est
Prionospio saccifera Mackie & Hartley, 1990			unk		expS				est
Pseudonereis anomala Gravier, 1900	exp		est		est				est
Pseudopolydora paucibranchiata (Okuda, 1937)	exp	exp	est	exp	est	exp	exp	exp	est/inv
Spirobranchus kraussii (Baird, 1865)			exp		expS				est
Streblospio gynobranchiata Rice & Levin, 1998		exp			expN		inv		est
Amathia verticillata (delle Chiaje, 1822)	exp	exp	est/inv	est	est	exp	exp	unk	unk
Diadumene lineata (Verrill, 1869)		est		exp	est	exp	exp	unk	est
Clytia hummelincki (Leloup, 1935)	exp		exp	unk	est	exp		exp	exp
Clytia linearis (Thorneley, 1900)	exp		est	exp	est	exp		exp	est
Garveia franciscana (Torrey, 1902)	exp	est	exp	exp	est	exp	exp	exp	exp
Macrorhynchia philippina Kirchenpauer, 1872			exp		expS				est
Cassiopea andromeda (Forsskål, 1775)	exp		est	expS	cas	exp			est
Phyllorhiza punctata Lendenfeld, 1884			est		est				est
Rhopilema nomadica Galil, Spanier & Ferguson, 1990			cas		cas				est
Grandidierella japonica Stephensen, 1938		exp		exp	est		exp	exp	exp
Megabalanus tintinnabulum (Linnaeus, 1758)	exp	exp	est	unk	est	exp	exp	unk	exp
* *Heterosaccus dollfusi* Boschma, 1960			exp		expS				est
* *Mytilicola orientalis* Mori, 1935		exp			expN		exp		
Oithona davisae Ferrari & Orsi, 1984		est			exp		est		est
Pseudodiaptomus marinus Sato, 1913		exp		exp	est		exp	est	
Atergatis roseus (Rüppell, 1830)			est		expS				est
Callinectes sapidus Rathbun, 1896	est	est	est	est	est	est	est	exp	est
Charybdis japonica (A. Milne-Edwards, 1861)	exp	exp	exp	exp	cas	exp	exp	exp	exp
Charybdis longicollis Leene, 1938			est		expS				est
Eriocheir sinensis H. Milne Edwards, 1853		exp		exp	cas		cas	exp	exp
Hemigrapsus sanguineus (De Haan, 1835)		exp		cas	exp		cas		exp
* *Hemigrapsus takanoi* Asakura & Watanabe, 2005		exp		exp	expN		exp	exp	exp
Ixa monodi Holthuis & Gottlieb, 1956			est		expS				est
Leptochela pugnax de Man, 1916			exp		expS				est

Species	**AL**	**BG**	**GR**	**HR**	**IT**	**ME**	**RO**	**SL**	**TR**
Matuta victor (Fabricius, 1781)			exp		expS				est
Metapenaeopsis aegyptia Galil & Golani, 1990			est		expS				est
Metapenaeopsis mogiensis consobrina (Nobili, 1904)			est		expS				est
Metapenaeus monoceros (Fabricius, 1798)			exp		expS				est
Metapenaeus stebbingi Nobili, 1904			exp		expS				est
Myra subgranulata Kossmann, 1877			est		expS				est
Ogyrides mjoebergi (Balss, 1921)			exp		expS				est
Penaeus aztecus Ives, 1891			inv		est	cas			inv
Penaeus japonicus Spence Bate, 1888	unk	exp			cas		exp		unk
Penaeus pulchricaudatus Stebbing, 1914			est		expS				est
Penaeus semisulcatus De Haan, 1844 [in De Haan, 1833-1850]			exp		exp				est
Percnon gibbesi (H. Milne Edwards, 1853)	est		inv	est	est	exp		exp	est
Portunus segnis (Forskål, 1775)	exp		est		est				est
Rhithropanopeus harrisii (Gould, 1841)		est/inv			est		inv		exp
Trachysalambria palaestinensis (Steinitz, 1932)			est		cas				est
Erugosquilla massavensis (Kossmann, 1880)			est		cas				est
Beroe ovata Bruguière, 1789		est/inv	cas		unk		inv	cas	est
Mnemiopsis leidyi A. Agassiz, 1865	exp	est/inv	est	est	est/inv	exp	inv	est	est
Anadara kagoshimensis (Tokunaga, 1906)	est	est/inv	exp	est	est/inv	exp	inv	est	est
Anadara transversa (Say, 1822)	exp		est	est	est/inv	exp		est	est
Arcuatula senhousia (Benson, 1842)	unk	exp		est	est/inv	unk	cas	inv	est
Brachidontes pharaonis (P. Fischer, 1870)	est		est	unk	est			cas	est
Chama pacifica Broderip, 1835			est		expS				est
Clementia papyracea (Gmelin, 1791)			cas		expS				est
Dendostrea cf. *folium* (Linnaeus, 1758)	unk		est		expS				est
Fulvia fragilis (Forsskål in Niebuhr, 1775)	est		est		est				est
Gafrarium savignyi (Jonas, 1846)			exp		expS				est
Goniobranchus annulatus (Eliot, 1904)			est		expS				est
Gouldiopa consternans (Oliver & Zuschin, 2001)			exp		expS				cas
Magallana/Crassostrea sp./spp.	unk	exp	est	est	est/inv	unk	cas	inv	est
Malleus regula (Forsskål in Niebuhr, 1775)			est		expS				est
Mya arenaria Linnaeus, 1758		est/inv	est	exp	est		inv	exp	est
Paratapes textilis (Gmelin, 1791)			exp		expS				cas

	Species	AL	BG	GR	HR	IT	ME	RO	SL	TR
	Pinctada imbricata radiata (Leach, 1814)	est		inv	est	est	est		exp	est
	Ruditapes philippinarum (Adams & Reeve, 1850)	est	exp	exp	est	inv	cas	exp	est	est
	Spondylus spinosus Schreibers, 1793			cas		expS				est
	Xenostrobus securis (Lamarck, 1819)		exp			est		exp		exp
	Bulla arabica Malaquias & Reid, 2008			est		expS				est
	Bursatella leachii Blainville, 1817	est		est	est	est	est		est	est
	Conomurex persicus (Swainson, 1821)	unk		est		expS	exp			est
	Corambe (Doridella) obscura (A. E. Verrill, 1870)		est			expN		inv		
	Diodora ruppellii (G. B. Sowerby I, 1835)			exp		expS				est
	Finella pupoides A. Adams, 1860			exp		expS				est
	Melibe viridis (Kelaart, 1858)	exp		est	est	est	est		cas	est
*	*Murex forskoehlii* Röding, 1798			exp		expS				exp
*	*Ocinebrellus inornatus* (Récluz, 1851)		exp			expN		exp		exp
	Pseudominolia nedyma (Melvill, 1897)			exp		expS				est
	Pyrunculus fourierii (Audouin, 1826)			cas		expS				est
	Rapana venosa (Valenciennes, 1846)	unk	inv	cas		est		inv	est	est
	Rhinoclavis kochi (Philippi, 1848)			cas		expS				est
	Sepioteuthis lessoniana Férussac [in Lesson], 1831			est		expS				est
	Syrnola fasciata Jickeli, 1882			est		expS				est
*	*Aquilonastra burtoni* (Gray, 1840)			exp						exp
	Diadema setosum (Leske, 1778)			est		expS				est
	Ophiactis savignyi (Müller & Troschel, 1842)			cas		expS				est
	Ascidiella aspersa (Müller, 1776)	exp	exp	est	exp	est	exp	exp	est	est
	Botrylloides giganteum (Pérès, 1949)			exp		unk				exp
*	*Botrylloides nigrum* Herdman, 1886	exp		exp	expS	expS				exp
	Ciona robusta Hoshino & Tokioka, 1967	exp	exp	exp	exp	est	exp	exp	exp	est
	Diplosoma listerianum (Milne Edwards, 1841)	exp	exp	est	exp	est	exp	exp	exp	est
*	*Ecteinascidia thurstoni* Herdman, 1890	exp		exp	exp	exp	exp		exp	exp
	Herdmania momus (Savigny, 1816)			est		expS				est
	Microcosmus exasperatus Heller, 1878			exp		expS				est
	Microcosmus squamiger Michaelsen, 1927		exp	exp		est		exp		exp
	Phallusia nigra Savigny, 1816			est		expS				est
*	*Polyclinum constellatum* Savigny, 1816			exp		expS				exp

	Species	AL	BG	GR	HR	IT	ME	RO	SL	TR
*	*Rhodosoma turcicum* (Savigny, 1816)			exp		expS				exp
	Styela clava Herdman, 1881	exp	exp	exp	exp	exp	exp	exp	exp	unk
	Styela plicata (Lesueur, 1823)	exp	exp	exp	est	est	exp	exp	est	exp
	Symplegma brakenhielmi (Michaelsen, 1904)			est		expS				est
	Apogonichthyoides pharaonis (Bellotti, 1874)	exp		est		expS				est
	Atherinomorus forskalii (Rüppell, 1838)			est		expS				est
	Cheilodipterus novemstriatus (Rüppell, 1838)			exp		expS				est
	Cynoglossus sinusarabici (Chabanaud, 1931)			exp		expS				est
	Decapterus russelli (Rüppell, 1830)			exp		expS				est
	Etrumeus golani DiBattista, Randall & Bowen, 2012			est		cas				est
	Fistularia commersonii Rüppell, 1838	exp		inv	cas	est	cas		exp	inv
	Jaydia smithi Kotthaus, 1970			exp		expS				est
	Lagocephalus sceleratus (Gmelin, 1789)	exp		inv	est	est	cas		exp	inv
	Lagocephalus suezensis Clark & Gohar, 1953			est		expS				est
	Liza carinata (Valenciennes, 1836)			cas	unk	expS				est
	Parexocoetus mento (Valenciennes, 1847)	cas		est		expS				est
	Pempheris rhomboidea Kossmann & Räuber, 1877			est		expS				est
	Planiliza haematocheila (Temminck & Schlegel, 1845)		est	est		expS		inv		est
	Plotosus lineatus (Thunberg, 1787)			exp		expS				est
	Pteragogus trispilus Randall, 2013			est		expS				est
	Pterois miles (Bennett, 1828)	exp		est/inv		cas	exp			est/inv
	Sargocentron rubrum (Forsskål, 1775)			est		expS				est
	Saurida lessepsianus Russell, Golani & Tikochinski, 2015	cas		est		cas				est
	Scomberomorus commerson (Lacepède, 1800)			est		expS				est
	Siganus luridus (Rüppell, 1829)			inv	est	est	cas			inv
	Siganus rivulatus Forsskål & Niebuhr, 1775			inv	cas	cas				inv
	Sillago suezensis Golani, Fricke & Tikochinski, 2013			exp		expS				est
	Sphyraena chrysotaenia Klunzinger, 1884	exp		est	cas	expS				est
	Sphyraena flavicauda Rüppell, 1838			est		expS				est
	Stephanolepis diaspros Fraser-Brunner, 1940			est	exp	est	cas		cas	est
	Upeneus moluccensis (Bleeker, 1855)			est		cas				est
	Upeneus pori Ben-Tuvia & Golani, 1989			est		cas				est

ing: 2), whereas *P. miles* was the only species that had solely been introduced through the Suez Canal (Table A, on-line supplement). There is an expected likelihood of all species to further expand their distribution in the ESENIAS countries, either unaided or through shipping, a possibility that in some cases is medium to high (Table 2). Out of the ten selected species, six have already impacts on the ESENIAS countries, mainly on ecosystems/biodiversity and human health (Table 2), yet they are all expected to have new/additional impacts (Table 2), as in other invasive areas, that should be addressed/mitigated to the best possible extent.

Alexandrium monilatum (J.F.Howell) Balech (Fig. 2)

Alexandrium monilatum is a thecate, chain-forming dinoflagellate. It is a coastal and estuarine planktonic species of warm temperate and tropical environments (TAYLOR *et al.,* 1995; STEIDINGER & TANGEN, 1996). The species is found in the Atlantic littoral of the USA as follows: Gulf of Mexico (CONNELL & CROSS, 1950; RAY & ALDRICH, 1967); Florida (HOWELL, 1953); Chesapeake Bay (MAY *et al.,* 2010). in the Caribbean Sea: Venezuela (HALIM, 1967), and in the tropical Pacific Ocean off Ecuador (BALECH, 1995). It was reported for the first time at the Bulgarian coast of the Black Sea in 1991 (MONCHEVA *et al.,* 1995), where it was also later observed (MONCHEVA *et al.,* 2001; NESTEROVA *et al.,* 2008). In 2001, the species has been detected also in Odessa port, Ukraine (ANONYMOUS, 2015).

Alexandrium monilatum has been associated with bloom formation (HOWELL, 1953; PERRY *et al.,* 1979; HARDING *et al.,* 2009) and fish kills due to ichthyotoxins (GATES & WILSON, 1960; RAY & ALDRICH, 1967). Whole cells and crude extracts of *A. monilatum* have been shown experimentally to be lethal to mice, rats, fish, shellfish and cockroaches (GATES & WILSON, 1960; ALDRICH *et al.,* 1967; CLEMONS *et al.,* 1980a, b; ERKER *et al.,* 1985; MAY *et al.,* 2010). It was reported that *A. monilatum* produce PSP toxins (HSIA *et al*., 2006), yet, to date, the species has not been related to toxic events in the Black Sea. It has been reported in blooming concentration along the Bulgarian Black Sea coast (MONCHEVA et al., 1995, 2001). Blooming species cause water discoloration, especially in late summer, as well as community changes (MONCHEVA & KAMBURSKA, 2002; MONCHEVA *et al.,* 1995, 2001; VELIKOVA *et al.,* 1999). Other socio-economic effects include beach water aesthetics with a negative impact on recreation (KATSANEVAKIS *et al.,* 2014).

Fig. 2. Alexandrium monilatum *(J.F.Howell) Balech (left; figure from WALKER & STEIDINGER (1979)) and its distribution in the Black Sea (TRICHKOVA et al., 2017)*

Table 2. Selected features used for horizon scanning and risk assessment, for the ten species that fact sheets were compiled within the ESENIAS-Tools project. AL=Albania, BG=Bulgaria, GR=Greece, HR=Croatia, IT=Italy, ME=Montenegro, RO=Romania, SL=Slovenia, TR=Turkey. VEC= potential vector of expansion, S=shipping, U=unaided, RoS= risk of spread, M=Medium, H=high, L=low

Species	**Presence in ESENIAS countries**		**VEC**	**RoS**	**densities/population explosions**	**Impacts in ESENIAS countries**	
	present	**expected**				**current**	**potential**
Alexandrium monilatum	BU	HR, IT, RO	S	M	blooms in the Black Sea	impact on ecosystem (consumption of nutrients, light decrease)	toxic event; ecosystem degradation
Bonnemaisonia hamifera	GR, IT, TR	AL, BG, HR, ME, RO	S,U	M/H		impact on ecosystem (growth of other algal species)	
Streblospio gynobranchiata	RO, TR	BG, IT	S	M	high densities in the Romanian coasts and in Izmir Bay	impact on ecosystem (alteration of indigenous biocoenoses)	invasion in polluted areas causing ecosystem degradation
Cassiopea andromeda	GR, IT, TR	AL, HR, ME	U	L	high densities in Greece and Turkey	impact on human health	impact on biodiversity (through predation) and ecosystem services (e.g. tourism)
Oithona davisae	BG, RO, TR	IT	S	L M	established populations in the Black Sea	replacement of native species (e.g. *Oithona nana*)	effects on the abundance of flagellates and bacteria
Penaeus aztecus	GR, IT, ME, TR		U	M	dense exploitable populations in Greece and Turkey	none to date	effects on biodiversity (competition with the native *Penaeus kerathurus*)
Mya arenaria	BU, GR, IT, RO, TR	HR, SL	U	H	high densities in the Black Sea	invasive in the Black Sea, causing regime shifts and changes in the native communities	invasive in other areas of its distribution causing effects on the ecosystem
Diadema setosum	GR, TR	IT	U	M	spreading rapidly in Greece	none to date	human health; biodiversity (through predation) and ecosystem services (e.g. tourism)
Microcosmus exasperatus	TR	GR, IT	S,U	M	unknown	none to date	effects on biodiversity (biofouling and competition with other sedentary species)
Pterois miles	GR, IT, TR	AL, ME	U	M	increasing populations in Greece	none to date	human health; biodiversity (through predation)

Bonnemaisonia hamifera Hariot (Fig. 3)

Bonnemaisonia hamifera is a red alga with a heteromorphic cycle with alternation between a large, coarsely branched gametophyte and a delicate filamentous sporophyte, originally described as a separate species (*Trailliella intricata* Batters). Native in the North West Pacific, *B. hamifera* was first recorded in Europe in the British Isles (Dorset) in 1890. The species was probably introduced by shipping. Nowadays, it is widely distributed on southern and western coasts to Shetland Isles, and can be abundant in certain locations, notably where there are large, lagoon-like lower intertidal pools. In the Mediterranean Sea, the first record was as "*Trailliella intricata*" in 1909 from Tunisia. The gametophytic phase seems to have been observed only in Spain, close to Gibraltar and in Catalonia, whereas the sporophytic phase has been recorded all around the basin (VERLAQUE *et al.,* 2015). *Bonnemaisonia hamifera* can be found on rocks and on various benthic organisms.

In the north-eastern Atlantic, *B. hamifera* can have a negative impact as an ecosystem engineer by forming dense epiphytic growth on host algae (JOHANSSON *et al.,* 1998), thus reducing light and nutrient availability for those algae, in addition to preventing competing algae to colonize (SVENSSON *et al.,* 2013). By its high ratio of surface to volume, it has a greater potential for rapid uptake of nutrients in comparison to their host algae (LITTLER & LITTLER, 1980).

Native herbivores strongly preferred native algae to *B. hamifera*. *Bonnemaisonia hamifera* produces chemical grazer deterrents, mainly the secondary metabolite 1,1,3,3-tetrabromo-2-heptanone not known from the native algae of the invaded area and the importance of the chemical defence was underlined by the feeding preference of herbivores for *B. hamifera* individuals with an experimentally depleted content of 1,1,3,3-tetrabromo-2-heptanone (ENGE *et al.,* 2012). Herbivores used *B. hamifera* as a refuge for fish predation. As a result, the presence of herbivores decreases the performance of neighbouring native algae and increases growth and relative abundance of *B. hamifera* (ENGE *et al.,* 2013). The 1,1,3,3-tetrabromo-2-heptanone also works as an allelopathic compound that prevents settlement of epiphytic organisms and that can be transferred from *B. hamifera* to a native host algal species by direct contact, with an active and unaltered function, i.e. in inhibiting recruitment of native competitors (SVENSSON *et al.,* 2013). The secondary metabolite affects the natural fouling community by altering the composition, and changed the diversity by increasing the evenness and decreasing the density, indicating a broad specificity of this metabolite against bacterial colonization (e.g. PERSSON *et al.,* 2011).

Optimal experimental conditions for the biomass production of the sporophytic phase are represented by a combination of temperatures of 15-20°C, photon irradiances of 20-30 µmol photons $m^{-2} s^{-1}$ and long daylengths (16:8 h L:D) (NASH *et al.,* 2005).

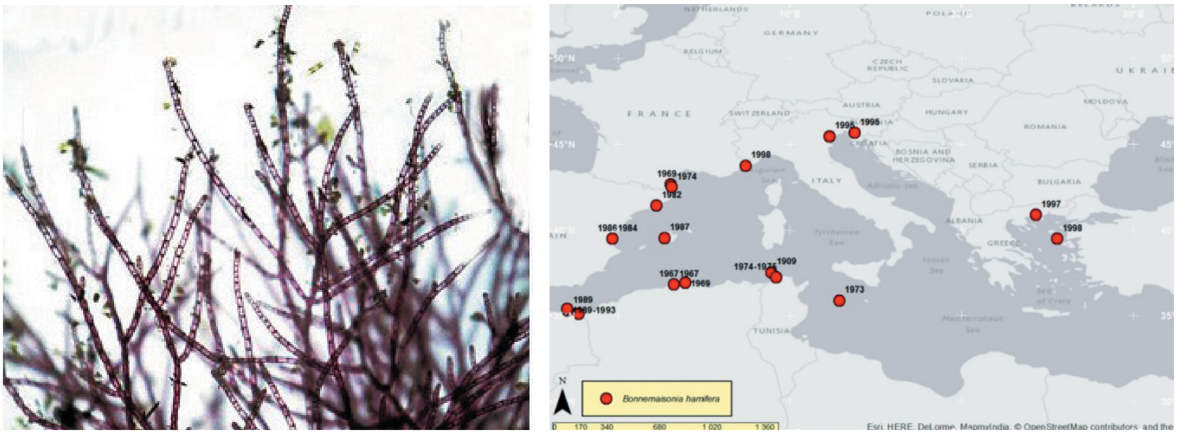

Fig. 3. Bonnemaisonia hamifera *Hariot (left; Photo: Marjan Richter) and its distribution in the Mediterranean Sea (TRICHKOVA et al., 2017). Scale bar=1 cm*

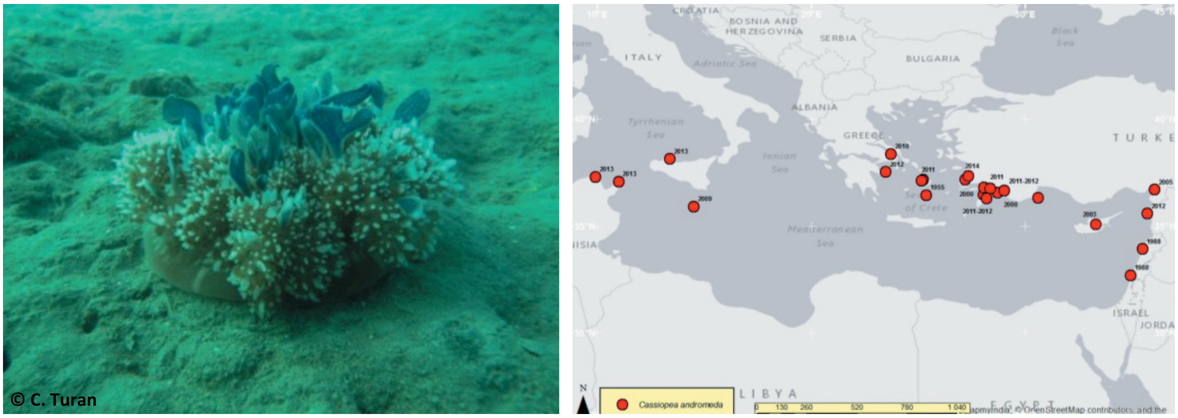

Fig. 4. Cassiopea andromeda *(Forsskål, 1775) (left; Photo: Cemal Turan) and its distribution in the Mediterranean Sea (TRICHKOVA et al., 2017; modified)*

Cassiopea andromeda (Forsskål, 1775) (Fig. 4)

Cassiopea andromeda is a globally distributed in warm coastal regions semi-sessile, planktonically dispersed scyphomedusa, typically found in shallow lagoons, intertidal sand or mud flats, and around mangroves in Florida, and in the Caribbean. Its native distribution extends from the West Indian Ocean to West Pacific Ocean, and the tropical Atlantic (HOLLAND *et al.*, 2004). The presence of *C. andromeda* in the Mediterranean Sea dates prior to 1900 (MAAS, 1903).

Cassiopea andromeda is venomous (PALOMARES & PAULY, 2016) and can kill smaller fish and other marine organisms with which they come into contact, and as such is a threat to the ecosystem functioning. The species might cause an imbalance in a closed area like a bay or lagoon, but its motility is very limited, and is unlikely to spread very much.

Cassiopea andromeda is not highly dangerous because its sting is very mild. Although there has not been any record on hospitalized events of *C. andromeda* stings, this jellyfish stinging cell can possibly cause discomfort on thin or sensitive skin, as well as the eyes and lips. Moreover, *C. andromeda* do not normally swim in the water but lie on the bottom with their umbrella facing and touching the substratum and their arms, which are short and shrubby, pointing towards the surface. Swimming over the jellyfish (especially using swim fins) may cause the transparent, essentially invisible, sheets of the mucus to rise in the water column. The stings, appearing in the form of a red rash-like skin irritation, are known for being extraordinarily itchy.

Due to its appearance and nature it may bring people snorkelling or diving into the areas in which the jelly lives, adding to the local economy.

Cassiopea andromeda feeds on copepods, cladocerans, mollusc larvae and on pelagic fish eggs and larvae (PALOMARES & PAULY, 2016). The predation upon fish larvae and eggs could potentially cause impacts on fisheries, especially in the case of consumption of commercial species, yet this is a hypothesis that needs to be further investigated.

No risk assessment analysis on biodiversity, ecosystem services or economy has been conducted. However, its presence in Turkish and Greek coastal areas that are favourite tourist destinations may lead to significant loss of ecosystem services.

Mya arenaria Linnaeus, 1758 (Fig. 5)

Mya arenaria is a bivalve that lives burrowed in muddy, sandy and gravelly sediments. It adapts well to a wide range of salinities and temperatures, and can survive both in pristine and disturbed/polluted habitats, including oxygen depleted environments, down to ≥200 m deep.

Archaeological evidence seems to suggest that *Mya arenaria* originated in the Pacific Ocean during the Miocene, and extended its range in the early Pliocene to the Atlantic.

Fig. 5. Mya arenaria *Linnaeus, 1758 (left; Photo: Edoardo Turolla) and its distribution in the Mediterranean and Black Seas (TRICHKOVA et al., 2017; modified)*

However, the Pacific and European populations became extinct during the Pleistocene glaciations, leaving only the Northwest Atlantic population alive. *Mya arenaria* only recolonized both areas in historical times, and now occurs in a wide North East Atlantic area from the Barents Sea to Portugal, including the Baltic Sea (STRASSER, 1999; CROSS *et al.*, 2016; LASOTA *et al.*, 2016). It was also recently sighted in the Mediterranean and Black Sea, including the Turkish Straits (Bosphorus and Marmara Sea), where its presence is confirmed in five ESENIAS countries (Fig. 5). There are no convincing records from the Dardanelles and the Turkish Black Sea so far, presumably due to lack of field studies.

Mya arenaria local abundances and establishment success vary within the different ESENIAS countries. It is established in the Mediterranean Sea and the Turkish Straits, but with very low abundances and/or restricted ranges except France, where the species spread and become abundant in the Gulf of Lion (ZIBROWIUS, 2002; CROCETTA & TUROLLA, 2011). In the Black Sea, soon after its first record from Ukraine (1966) (BESHEVLY & KALYAGIN, 1967), the species established and became dominant in the north western and western parts of the Black Sea, and in the Sea of Azov (ZOLOTAREV, 1996). On the Bulgarian shelf, *M. arenaria* is widely distributed on sandy sediments in low salinity waters and at some sites it reaches densities of 4860 individuals m^{-2} (MARINOV, 1990). In the north western part of the Black Sea it is especially numerous in the coastal zones on muddy sediments, where its biomass exceeds 1 kg m^{-2} (ZOLOTAREV, 1996).

Mya arenaria impacts vary within the different ESENIAS countries. No impacts have been reported for the Mediterranean and the Turkish Straits, but the taxon shows invasive properties in the Black Sea dominating the soft substratum communities, causing regime shifts and structural changes in native communities/invaded habitats, and affecting sediment and water-column characteristics (KATSANEVAKIS *et al.*, 2014).

In its native area, *M. arenaria* is considered a delicacy, and is harvested by commercial fishery for cookery purposes. On the contrary, to date, the species is not commercially exploited in Europe. It is also a food source for migrating shorebirds and for a wide number of sea inhabitants (fish, sandworms and crabs, among others) (COHEN, 2005). As a suspension feeder, it plays a crucial role in filtering and cleaning water sources, and can be used as a tool in regulating and enforcing pollution standards in water quality control. It sequesters carbon in the form of calcium carbonate used for shell creation (KATSANEVAKIS *et al.*, 2014).

Streblospio gynobranchiata Rice & Levin, 1998 (Fig. 6)

Streblospio gynobranchiata is a shallow-water tube-dwelling polychaete species, found in muddy sediments of estuaries, coastal areas and harbours, at depths ranging from 0.5 to 35.6 m, where it forms dense aggregations. CINAR et al. (2005b) reported densities of up to 34,740 individuals m^{-2}. It prefers the upper layer of the muddy sediments with high levels of organic enrichment, rich in hydrogen sulphide and

Fig. 6. Streblospio gynobranchiata *Rice & Levin, 1998 (left; Photo: Natalya A. Boltachova) and its distribution in the Mediterranean and Black Seas (TRICHKOVA et al., 2017)*

organic nitrogen (RADASHEVSKY & SELIFONOVA, 2013; BOLTACHOVA *et al.,* 2015). The tolerance of *S. gynobranchiata* to low concentrations of dissolved oxygen contributes to the colonization of substrates in severely polluted and physically degraded environments. *Streblospio gynobranchiata* is considered as one of the most successful pioneer and opportunistic species.

The native distribution area of this species is the western Atlantic (RICE & LEVIN, 1998; RADASHEVSKY & SELIFONOVA, 2013). It is one of the worst invasive species in the Mediterranean basin, where it was probably introduced via ships ballast waters (ÇINAR *et al.,* 2005a, b). It was first mentioned in the ESENIAS geographic area from the Aegean Turkish littoral (Izmir Bay), where it has been established since 2000 (ÇINAR *et al.*, 2005a, b; 2006; DAĞLI *et al.*, 2011). This species established large and dense populations in the Sea of Marmara (Istanbul area, Golden Horn Estuary, Bosporus Strait; ÇINAR *et al.,* 2009). It was also reported in the Black Sea (MURINA *et al.,* 2008; BOLTACHOVA, 2008; RADASHEVSKY & SELIFONOVA, 2013; BOLTACHOVA *et al.,* 2015; TEACĂ *et al.,* 2015) and the Caspian Sea (TAHERI *et al.,* 2008). Recently, in 2015, this species was mentioned from the north-eastern part of the Azov Sea, from Taganrog Bay and from the Don River Delta (SYOMIN *et al.,* 2017).

To date, the impact in the ESENIAS area is a local one, with populations establishing especially in harbour areas and polluted or degraded habitats. The dense populations of the polychaete change the indigenous biocoenoses, especially in polluted soft-bottom benthic habitats (ÇINAR *et al.,* 2005b, 2011).

Dense populations and high biomass of *S. gynobranchiata* and the position it holds in the food-web as a deposit feeder in areas highly polluted with organic matter have an obvious ecological impact. In such habitats, *S. gynobranchiata* prove to be a dominant species, as well as a pollution indicator. As a result of the species biology and the large ecological tolerance of *S. gynobranchiata*, harbour areas with huge traffic and narrow gulfs with muddy bottoms are the most sensitive areas where this spionid polychaete could establish and develop large and dense populations replacing native species. The only measures to avoid the establishment of this species could be maintaining low pollution and eutrophication levels and avoiding discharge of ballast waters in the coastal areas.

Oithona davisae Ferrari & Orsi, 1984 (Fig. 7)

Oithona davisae is a pelagic cyclopoid copepod which could be the most abundant mesozooplankton species in its native habitat. It is widely spread around the Black Sea: during the first years the species developed mainly in the coastal waters but now could reach also deep waters above the depth 1000 m. In the coastal and open Black Sea this new *Oithona* taxon occupied the niche of the disappeared *Oithona nana* Giesbrecht, 1893 (SHIGANOVA *et al.,* 2012).

It is widely accepted that *O. davisae* is originally endemic to the temperate coastal waters of East Asia and its occurrence in other remote regions is due to anthropogenic introduction, mainly through ballast waters (FERRARI & ORSI, 1984; NISHIDA, 1985; HIRAKAWA, 1988). *Oithona*

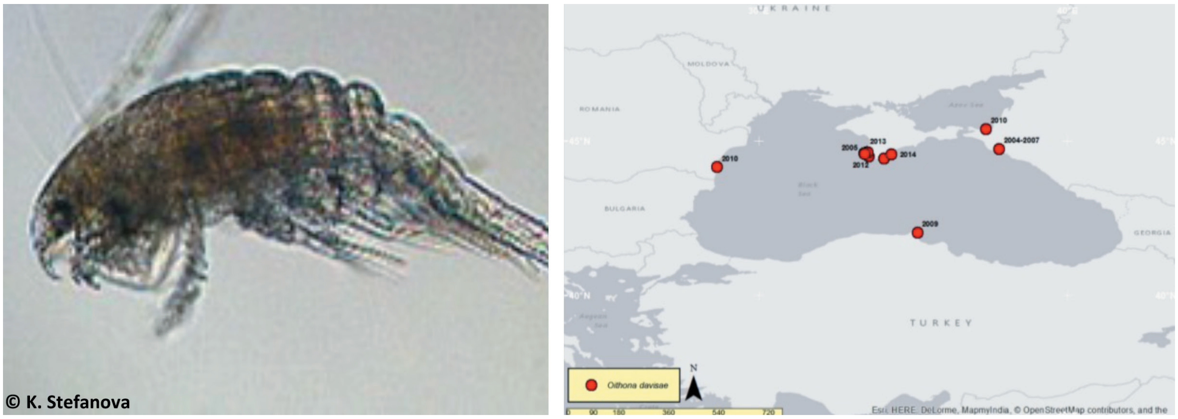

Fig. 7. Oithona davisae *Ferrari & Orsi, 1984 (left; Photo: Kremena Stefanova) and its distribution in the Black Sea (TRICHKOVA et al., 2017)*

davisae usually inhabits eutrophic embayments (UYE & SANO, 1995; ALMEDA *et al.,* 2011) and is indigenous to Japan and the China Seas, and many coastal areas (RAZOULS *et al*., 2012), but it is invasive along the USA west coast (FERRARI & ORSI, 1984) and the Spanish Mediterranean (SAIZ *et al.,* 2003). The invasive successful establishment and expansion of the thermophilic copepod *O. davisae* in the cold Black Sea is evidence of the extremely high adaptive plasticity of this species. The successful establishment of *O. davisae* to the Black Sea seems related to phytoplankton structure changes including a prevalence of small flagellates due to climate-driven effects (NESTEROVA *et al.,* 2008; MAVRODIEVA, 2012). It appears the species has expanded its distribution in the Azov Sea, as it: it has been reported in the Temruk Bay in 2010 (SVISTUNOVA, 2013).

At present, *O. davisae* successfully competes with the larger copepods *Acartia tonsa* Dana, 1849 and *Acartia clausi* Giesbrecht, 1889 in the Black Sea. It is still not clear why *O. davisae* successfully occupied the ecological niche of the disappeared *O. nana*, while the latter is not successful to return. Because of the specific features of *O. davisae,* e.g. feeding on flagellates and not on diatoms and detritus, their mass development could affect the abundance of flagellates and bacteria (ROFF et al., 1995).

Penaeus aztecus Ives, 1891 (Fig. 8)

Penaeus aztecus is a shrimp species, an active swimmer and burrower (SMITHSONIAN MARINE STATION AT FORT PIERCE, 2016), with the juveniles living also in estuarine habitats. It is found from the coastline up to 160 m deep, on muddy or sandy-muddy bottoms, sometimes mixed with sand, clay or broken shells. The adults are mostly active at night, burying in the substrate at daytime (HOLTHUIS, 1980; TAVARES, 2002).

The native distribution of the species is in the western Atlantic (PALOMARES & PAULY, 2016). *Penaeus aztecus* has also been introduced to New Caledonia and French Polynesia in the 1970s for aquaculture purposes (PALOMARES & PAULY, 2016). The first record of the species in the Mediterranean Sea was in 2009 in Antalya Bay (DEVAL *et al.,* 2010), and by 2013 the species had a well-established population in the area (GÖKOĞLU & ÖZVAROL, 2013; ÖZVAROL & GÖKOĞLU, 2014). Nowadays, *P. aztecus* has been reported from various areas throughout the Mediterranean, revealing the fast spreading of the species in the basin.

The mode of introduction of *P. aztecus* in the Mediterranean is still not clear. Some authors consider that it was most likely transferred from the USA through ballast waters (DEVAL *et al.,* 2010; KEVREKIDIS, 2014), whilst more recent discussions (CRUSCANTI *et al*., 2015; GALIL *et al*., 2016) suggest that it may be a result of illegal introductions (an aquaculture release/escapee). Yet, both hypotheses need further investigation.

To date, no impacts have been reported for the Mediterranean, but as the species shares the same niche and has similar biological traits with

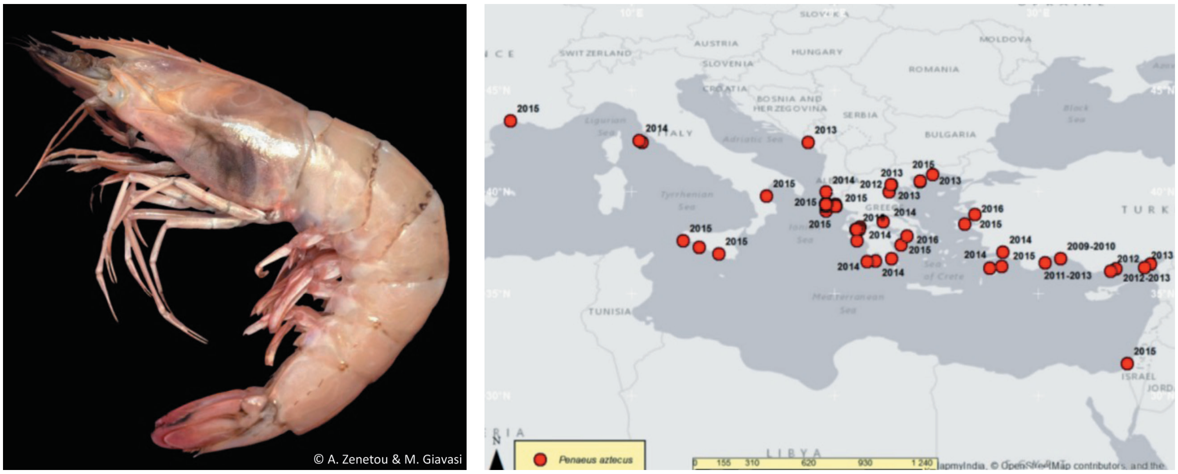

Fig. 8. Penaeus aztecus *Ives, 1891 (left; Photo: Argyro Zenetos & Maria Giavasi) and its distribution in the Mediterranean Sea (TRICHKOVA et al., 2017)*

the indigenous commercial *Penaeus kerathurus* (Forskål, 1775) (KEVREKIDIS, 2014, 2015) the interaction amongst the two species should be monitored and assessed. In the Mediterranean, *P. aztecus* is caught with both bottom trawlers and trammel nets, along with *P. kerathurus*. Due to the low catches, it is not yet marketed nor reported separately. Nevertheless, the larger size it can attain compared to that of *P. kerathurus*, and given the fact that its presence in the catches is constantly increasing (GÖKOĞLU & ÖZVAROL, 2013), may result in its commercial exploitation in the Mediterranean Sea. Yet, the fact that *P. aztecus* is infested by the parasitic isopod *Epipenaeon ingens* (Nobili, 1906), combined with the fact that parasitic bopyrid isopods as *E. ingens* have been found to affect its growth and reproduction (KORUN *et al.*, 2013 and references therein), might lead to a natural control of *P. aztecus* populations. However, this hypothesis needs to be monitored and further investigated.

Diadema setosum (Leske, 1778) (Fig. 9)

Diadema setosum is a venomous sea urchin (needlespined urchin, long-spined sea urchin) with distinctively delicate hollow spines that inhabits hard substrata, rocks covered with vegetation, and coral reefs. It is widely distributed in the West Indo-Pacific, from the Red Sea, Arabian Gulf, East coast of Africa, to India, Australia and Japan at depths ranging from 0 to 70 m. In the Red Sea, Gulf of Thailand and other native regions, it is the most common sea urchin and one of the most abundant benthic invertebrates.

Fig. 9. Diadema setosum *(Leske, 1778) (left; Photo: A. Liami) and its distribution in the Mediterranean Sea (TRICHKOVA et al., 2017; modified)*

The tropical sea urchin fauna, which survived the Messinian crisis, but the sudden cooling that started with the Arctic glaciation 2.58 million years ago, led to the end of the tropical fauna of the Mediterranean during the third Pliocene phase (POR, 2009). Yet, *Diadema*, re-colonized the Mediterranean after an interruption of more than two million years (YOKES & GALIL, 2006). Nowadays, the species is established in the eastern Mediterranean Sea (Fig. 9).

No impact on biodiversity has been reported for the Mediterranean. It is a food source for many reef fishes. The most notable predators of adult sea urchins in the tropical Indo-Pacific are certain large reef fishes, particularly the larger wrasses, triggerfishes, puffers and porcupine fishes. In coral reef aquaria, it offers useful microhabitats to many organisms and it is considered an excellent algae controller. The risk of possible overgrazing phenomena in the ESENIAS countries deserves further study.

Diadema setosum is of medical importance. The species requires particular care when handling or working around it. Its long, slender spines may inflict painful injuries on the unwary swimmers, divers and fishermen. The spines are brittle and hollow, with barbed tips that penetrate the skin and remain imbedded in the flesh, releasing venom from their tissue and lumen. The venom may cause redness, swelling, and acute pain, which subsides after a few hours; however, spine fragments are difficult to remove, and healing may take several weeks (YOKES & GALIL, 2006). The venom of *D. setosum* is not at all fatal to humans.

Edible and eaten in some native areas, but it is not very palatable. *Diadema setosum* is also involved in the marine aquarium trade.

Microcosmus exasperatus Heller, 1878 (Fig. 10)

Microcosmus exasperatus is a solitary ascidian with long siphons and leathery bright orange tunic with a few encrustations around the base. It typically attaches to natural and mostly artificial marine hard substrates, forming dense aggregations, which may be heavily fouled by a numerous epibionts.

Microcosmus exasperatus shows a circum-tropical distribution, being widely recorded from both the Atlantic and the Indo-Pacific regions, including the Red Sea. According to RAMOS-ESPLA *et al.* (2013) *M. exasperatus* was first recorded from Djerba Island (south of Tunisia) in 1998 and then it was observed on the coasts of Lebanon and Israel. It is commonly considered as being a Lessepsian immigrant due to multiple records from its easternmost shores. However, *Microcosmus* taxa are difficult to be identified, and therefore *M. exasperatus* worldwide identifications and possible spread patterns may be re-assessed by molecular taxonomy and phylogeography (genbank number: KT387604). Its alien Mediterranean distribution only includes

Fig. 10. Microcosmus exasperatus *Heller, 1878 (left; Photo: Noa Shenkar) and its distribution in the Mediterranean Sea (TRICHKOVA et al., 2017)*

one ESENIAS country and one main sea (Turkey, Mediterranean Sea), where the taxon is only known on the basis of a single specimen (RAMOS-ESPLÁ *et al.,* 2013). Studies that are more recent have revealed that it is established in the region (ME Cinar, unpubl. Info.). However, *M. exasperatus* was recently recorded from Cyprus (GEWING *et al.,* 2016), and its known distribution may be easily concealed by taxonomic impediments and low ascidian research effort.

Native *Microcosmus* taxa are commercially exploited in the Mediterranean and consumed in France, Italy and Greece due to their strong iodine taste. The high nutritional values and the most likely similar taste of the alien taxon would suggest a possible use for culinary purposes. The typical dense populations and heavy epibiont coverage of *M. exasperatus* may contribute to its establishment as an ecosystem engineer species, as already reported for other worldwide tunicates, and may cause problems when associated with other fouling species.

Pterois miles (Bennett, 1828) (Fig. 11)

A tropical marine fish species, *Pterois miles* is a reef associated species, living depth range 25-85 m, in a variety of habitats, including natural hard bottom, artificial structures, wrecks, bridge pilings, and seagrass (FROESE & PAULY, 2016).

Outside its native range, the species is reported along the southeastern United States coast from Florida to North Carolina, from Bermuda, Bahamas, and is becoming established in the Gulf of Mexico and the Caribbean, including northern South America, and Brazil (SCHOFIELD, 2010; FERREIRA *et al.,* 2015).

In the Mediterranean, a single record from Israel in 1991 (GOLANI & SONIN, 1992), had no follow up for about 20 years. However, a wave of *P. miles* invasion struck the eastern Mediterranean in the 2010s and is continuing at an increasing rate. In 2012 it was reported from Lebanon (BARICHE *et al.,* 2013), and a year later from Cyprus (EVRIPIDOU, 2013) where, in just one year, it had colonized nearly all of Cyprus' southeastern coast (JIMENEZ *et al.,* 2016). In the following years, the species was sighted in several Mediterranean locations (Fig. 11).

Pterois miles is native to the Indo-Pacific realm (FROESE & PAULY, 2016), and it is thought to have been introduced to the western Atlantic in the mid 1990's by aquarists (HARE & WHITFIELD, 2003). In the Mediterranean, the most likely introduction vector is considered to be the Suez Canal either through ballast water released from vessels crossing the canal (even though globally successful introductions of Scorpaenidae through ballast water have not been reported; see HARE & WHITFIELD, 2003) or by adult migration. However, secondary introductions through additional aquarium release events cannot be ruled out, and genetic connectivity studies are required to trace the origin of the Mediterranean populations. A recent genetic study presents evidence, albeit from a limited sample size, that supports the immigration of a few individuals from the Red Sea via the Suez Canal as the most

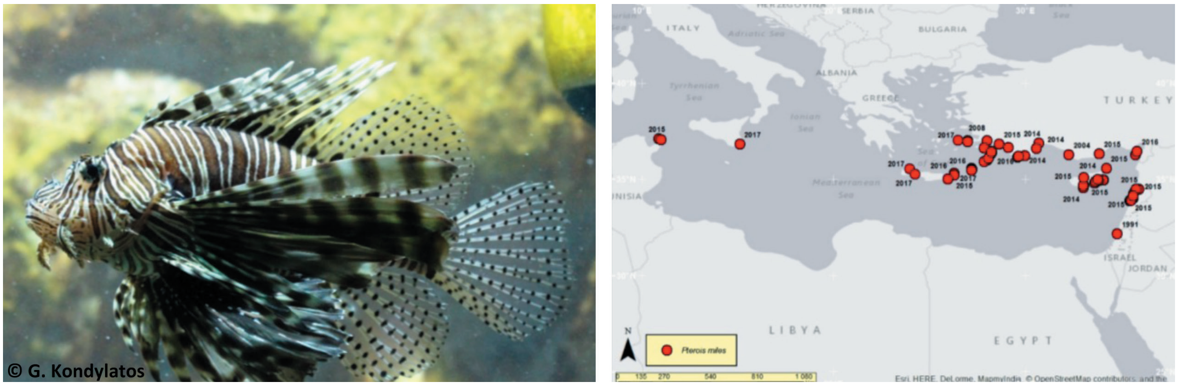

Fig. 11. Pterois miles *(Bennett, 1828) (left; Photo: Gerasimos Kondylatos) and its distribution in the Mediterranean Sea (TRICHKOVA et al., 2017; modified)*

likely introduction mechanism (BARICHE *et al,*. 2017).

In the west Atlantic invaded range, lionfish have reached densities that are far higher than those reported from their native range (KULBICKI *et al,*. 2012), exhibit extraordinary predation rates and are having dramatic impacts on the Caribbean ecosystem by displacing native species and disrupting food webs (LESSER & SLATERY 2011; ALBINS 2013).

In the Mediterranean, owing to the young age of the invasion, strong impacts on ecosystems have not been reported yet, as is the case in the invaded Atlantic distribution (for details see ALBINS & HIXON, 2008; LESSER & SLATERY, 2011; GREEN *et al.,* 2012, 2014; ALBINS, 2013; FALETTI *et al.,* 2013; BENKWITT, 2015; BALLEW et al., 2016; PALMER *et al.,* 2016) but are the subject of ongoing research. In addition, the full extent of the socioeconomic damage potentially caused by lionfish is yet to be realised, since the full spectrum and intensity of its ecological impacts and interactions with native species in not fully known.

Pterois miles has a direct impact on human health. The sting from its venomous spines can cause irritation, inflammation, pain and even serious complications in the case of an allergic reaction, putting fishermen, divers and other potential stakeholders at risk. On the other hand, it appears to be very attractive to divers, many of who specifically request dives in areas where the lionfish is known to be present (JIMENEZ *et al.,* 2017), at least in the Eastern Mediterranean, where the species is still a novel sighting, similar to what was observed in the Atlantic in the early stages of the invasion. Regardless of its venomous spines, the species is a popular aquarium fish and may create an extra source of income for fishermen who capture and supply the aquarium trade. Moreover, it is consumed in subsistence fisheries in its native area and can provide an alternative fish stock and food source in the invaded range. Its consumption is already promoted in some countries as a means of introducing control measures (NUÑEZ *et al.,* 2012).

CONCLUSIONS

This is the first effort to compile a list of marine invasive/potential invasive species in the ESENIAS countries. Such lists are an important initial step for the development of an early warning system, through a horizon scanning process (ROY *et al.,* 2015). Hence, based on the information presented here identification of future invasions in the ESENIAS countries is possible. It is essential, as a way forward for the countries referred herewith in, to further plan/enforce effective early warning and rapid response mechanisms, as well as take management measures for species that are already widely spread, in compliance with the EU Regulations (EU, 2014). Yet, such a list should be regularly revised and updated so that the management measures enforced would be effective.

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Uspostavljanje popisa morskih invazivnih vrsta u ESENIAS području: sadašnja situacija i buduća očekivanja

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SAŽETAK

U ovom radu predstavljamo popis invazivnih i potencijalno invazivnih vrsta na istoku i jugu Europske mreže za invazivne vrste (ESENIAS) u zemljama s morskim granicama.

Vrste su klasificirane prema postojećoj literaturi i procjeni stručnjaka, pa su tako utvrđene grupe povremenih, invazivnih i očekivanih vrsta. Podaci su dati za deset vrsta čija se važnost temelji na njihovom širenju i invazivnom karakteru.

Od 160 vrsta koje sadrži popis, 148 je već bilo prisutno u ESENIAS zemljama, dok je 9 invazivnih vrsta bilo prisutno u Sredozemnom ili u drugim europskim morima, a vjerojatno je da će se zabilježiti i u zemljama udruženim u ESENIAS. Većina vrsta je bile iz Crvenog mora / indo-pacifičkog podrijetla (97 vrsta, 60,6%). Italija, Turska i Grčka su zemlje s najvišom zastupljenošću vrsta (159, 152 i 139), zbog njihove proširene obale i broja znanstvenika koji rade na morskim invazivnim vrstama.

Najveći broj utvrđenih vrsta zabilježen je u Turskoj (116 vrsta), dok su u Italiji i Grčkoj najbrojnije vrste bile "očekivane" (85 i 48 vrsta, respektivno).

Istočne zemlje Jadranskog mora (npr. Albanija, Hrvatska, Crna Gora i Slovenija) imale su općenito nizak broj vrsta na ovom popisu, od kojih mnoge još "očekujemo" da pristignu iz susjednih zemalja: Grčke i Italije.

Konačno, najčešće su potencijalni putovi bili „transferni putnici" (balastna voda broda: 41 slučaj, obraštaj brodskog trupa: 55), dok je slijedilo i širenje lesepsijskih migranata (95 slučajeva).

Ovaj popis je namijenjen da služi kao sustav ranog upozorenja koji bi kroz proces skeniranja pomogao državama ESENIAS da daju prioritet invazivnim stranim vrstama, njihovim putovima i područjima veće vjerojatnosti pojavljivanja, kako bi se poduzele potrebne mjere upravljanja.

Ključne riječi: invazivne vrste, ESENIAS, Sredozemno more, Crno more